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Economy: The Case of the Canadian Dollar**

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The views expressed in this paper are those of the authors.
No responsibility for them should be attributed to the Bank of Canada.

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Abstract

The Bank of Canada is one of very few central banks that has made records of the intraday timing of its intervention operations available to researchers. The authors investigate the effectiveness of sterilized intervention in the Canadian dollar exchange rate market over the period January 1995 to September 1998. They employ an event study methodology and different criteria for success, and use both daily data and high-frequency (intraday) intervention and exchange rate data. The time period covers two distinct intervention regimes, characterized by mechanistic and discretionary intervention, respectively. Furthermore, the authors address the issue of currency co-movements by carrying out the analysis using both the readily observable Canadian dollar/U.S. dollar exchange rate and the Canadian dollar/U.S. dollar exchange rate adjusted for general currency co-movements against the U.S. dollar. When they analyze the high-frequency data, the authors find evidence that intervention systematically affects movements in the Canadian dollar/U.S. dollar exchange rate and in the desired direction, along with some evidence that intervention is associated with a reduction of exchange rate volatility. When investigating exchange rate movements around intervention events using daily data, the authors find some evidence supportive of effectiveness. These effects, however, are weakened when adjusting for currency co-movements against the U.S. dollar.

JEL classification: E58, F31, G14, G15

Bank classification: Exchange rates; Financial markets

Résumé

La Banque du Canada est l'une des rares banques centrales à mettre à la disposition des chercheurs des statistiques sur le moment de la journée où ses interventions ont lieu sur le marché des changes. Les auteurs évaluent l'efficacité des interventions stérilisées menées sur le marché du dollar canadien entre janvier 1995 et septembre 1998. Privilégiant une approche événementielle et retenant différents critères de réussite, ils utilisent des données tant quotidiennes qu'intrajournalières sur les interventions et le taux de change. La période examinée englobe deux régimes distincts : l'un se caractérise par des interventions automatiques et l'autre par des interventions discrétionnaires. Les auteurs prennent aussi en compte l'incidence des covariations générales des monnaies en faisant porter leur analyse à la fois sur le taux de change \$ CAN/\$ É.-U. directement observé et sur une variante de celui-ci corrigé des covariations d'autres monnaies par rapport au dollar américain. Lorsqu'ils se servent de données intrajournalières pour étudier l'évolution du taux de change avant et après l'intervention, les auteurs constatent que celle-ci a un effet systématique dans le sens souhaité sur les mouvements du dollar canadien; certains résultats laissent également croire que l'intervention s'accompagne d'une réduction de la volatilité du taux de change. Lorsque les données utilisées sont quotidiennes, l'intervention semble donner les effets voulus. Ceux-ci s'atténuent cependant dès que l'on tient compte des covariations des monnaies vis-à-vis du dollar américain.

Classification JEL : E58, F31, G14, G15

Classification de la Banque : Taux de change; Marchés financiers

1. Introduction

This paper studies the effectiveness of sterilized intervention in the Canadian dollar/U.S. dollar exchange rate (CAD/USD) over the period January 1995 to September 1998 using official, non-public intervention data provided by the Bank of Canada (BoC). The BoC has not intervened in the CAD/USD since that time. The data provide details by transaction, including the time when the intervention occurred, and allow us to study the impact of intervention at both the daily and the intraday frequency.¹

The data set and time period under study are of particular interest for two specific reasons. First, the BoC and the Swiss National Bank, to the best of our knowledge, are the only central banks that have made data on the intraday timing of their intervention operations available to researchers. The BoC intervention data are not publicly available, and have been explored in only a limited number of studies. Second, the time period under study covers two distinct intervention regimes. During the first regime, which covers the period from January 1995 to mid-April 1995, the BoC intervened based on a mechanistic, rules-based framework that was well understood by market participants. Intervention was designed to smooth movements in the exchange rate, not to target a level for the currency, with movements of a certain size in the CAD/USD triggering intervention. Appreciations and depreciations of the currency generated the same response. This approach to intervention resisted all trends in the currency and led to intervention on as many as 50 per cent of business days prior to April 1995. On 12 April 1995, a new intervention regime was adopted, designed to increase the impact of intervention by reducing its frequency, increasing the magnitude, allowing

¹ For surveys of the intervention literature, see Dominguez and Frankel (1993), Edison (1993), King (2003), and Sarno and Taylor (2001).

more discretion on the timing, and raising the visibility when it occurred.² Accordingly, the data set under study allows for a comparison of the effectiveness of intervention between mechanistic and discretionary intervention operations.

Only three studies have examined official, non-public BoC intervention data regarding the CAD.³ In a study conducted shortly after the adoption of the new framework, Murray, Zelmer, and McManus (1997) examine the impact of intervention on the implied volatility of over-the-counter CAD/USD call options from 1992 to 1996 using daily data. They find that intervention did not succeed in dampening volatility, except in a few cases where intervention was unexpected and unusually heavy towards the end of their sample. Beattie and Fillion (1999) provide an intraday analysis of the impact of intervention on implied CAD/USD volatility during the period April 1995 to January 1998. They find that mechanistic intervention was widely anticipated by the market and had no impact on volatility, whereas discretionary intervention was unanticipated and was associated with decreased volatility over short time periods. D'Souza (2002) provides a second high-frequency study of intervention in the CAD that tests market microstructure hypotheses.⁴ He suggests that foreign exchange dealers treat intervention by the central bank as any other customer order and that central banks must be able to forecast overall net customer trades at the time of intervention in order to be effective. In summary, the previous studies using either daily or high-frequency data find that intervention does not succeed in reducing the volatility of the currency,

² The objectives of intervention were not changed; they remained the maintenance of orderly market conditions in the context of a floating exchange rate system. Canada moved to a purely discretionary intervention policy in September 1998, where intervention occurs only in the most exceptional of circumstances. Since that time, the BoC has not intervened in the CAD/USD.

³ Studies of intervention by Phillips and Pippenger (1993) and Rogers and Siklos (2003) do not employ official BoC intervention data. Instead, they estimate the amount of daily intervention from changes in the level of foreign exchange reserves.

⁴ See Dominguez (2003) for an empirical market microstructure analysis of U.S. Federal Reserve intervention, and Pasquariello (2001) for a theoretical framework.

although the authors suggest that intervention that is unexpected and of greater intensity may have a short-term effect.

The two existing studies using official, high-frequency data provided by the Swiss National Bank are of particular relevance to our study. Fischer and Zurlinden (1999) focus on (scaled) exchange rate changes measured between consecutive interventions and use an irregular time-series model as the foundation for their analysis. They find that only the first intervention on a given day matters, and that subsequent interventions are ineffective. In a recent contribution, Payne and Vitale (2003) extend the analysis of Fischer and Zurlinden (1999). Within the context of an event study approach, they find that intervention operations have short-run effects on the Swiss franc (CHF)/USD exchange rate from 15 minutes to up to two hours following intervention. These effects are strongest when intervention is leaning-with-the-wind and when intervention is concerted with other major central banks. Payne and Vitale also find that markets partly anticipate intervention, because the exchange rate returns move in the 15-minute interval prior to interventions.⁵

Unlike intervention in the CHF/USD, intervention in the CAD/USD was always against-the-wind and was never concerted during the sample period. In addition, the framework for intervention changed over the sample period, allowing for a comparison of the effects of discretionary versus mechanistic intervention along with a general investigation of the effects of intervention.⁶

We use an event-study framework to analyze the effects of sterilized intervention on exchange rates. An event study is a very general test of a specific hypothesis and does not rely on a structural

⁵ See Pierdzioch and Stadtmann (2003) for an event study analysis of official, daily Swiss National Bank intervention data.

⁶ The April 1995 change in the exchange rate regime was not related to conditions in the foreign exchange markets or a change in the conduct of monetary policy, but resulted from cumulative discussions and study over the 1990s. The timing of the change may therefore be viewed as orthogonal to the market conditions that trigger intervention.

model of exchange rate determination. This is a desirable feature, given the lack of consensus over the appropriate structural exchange rate model. Payne and Vitale's (2003) event study examines the two hours before and after each intervention episode using a linear regression model, where the 15-minute percentage return is regressed on a signed indicator variable for intervention and a series of leads and lags of returns. This approach is not appropriate for intervention in the CAD/USD, because BoC intervention operations involved a number of intervention transactions that could continue for days or weeks at a time. Given the structure of the data at hand, we follow the event study approach of Fatum (2000) and Fatum and Hutchison (2003a, b), where clusters of intervention are identified, and exchange rate movements before and after the event are investigated.⁷

Eun and Lai (2004) point out that the issue of currency co-movements has not received much attention in the academic literature. Currency co-movement is of potential importance to our study, particularly since we focus on unilateral intervention conducted in a minor currency vis-à-vis a major currency. Canada is a small, open economy and spot turnover in its currency represented only 2 per cent of daily average foreign exchange turnover in 2001 (BIS 2002).⁸ By contrast, spot turnover in the majors—the USD, the European euro (EUR), and the Japanese yen (JPY)—represented 42 per cent, 22 per cent, and 13 per cent of spot turnover, respectively. Generalized movements against the USD may, therefore, mask exchange rate movements associated with BoC intervention operations. For example, if the CAD appreciates against the USD following a CAD purchase intervention, intervention may appear effective. If the USD depreciates against other

⁷ Djoudad et al. (2001) explore the time-series properties of the CAD/USD exchange rate, while Beattie and Fillion (1999) study the time-series properties of volatility in the CAD/USD.

⁸ The relative market shares are similar using the data from the 1995 and 1998 Bank for International Settlements (BIS) triennial surveys.

currencies in general, however, there is little reason to believe that the USD depreciation can be ascribed to the unilateral BoC intervention. We address this concern by analyzing the effectiveness of intervention using a "filtered" CAD/USD, calculated as the difference between the percentage change in the CAD/USD and a weighted average of the percentage change in the German Deutsche Mark (DEM), the JPY, and the British pound sterling (GBP). The results using the "filtered" CAD/USD may then be compared with the results using the unfiltered or "raw" CAD/USD to capture the impact of currency co-movements against the USD.

We use three criteria to test the effectiveness of intervention using both daily and high-frequency data. When daily data are used to investigate exchange rate movements around intervention events, intervention is systematically associated with a smoothing of exchange rate movements in the days following intervention, and with changes in the direction of the CAD/USD that begin several days after the intervention episode. These effects are generally weakened when the daily data for currency co-movements are adjusted against the USD, which suggests that market movements, rather than intervention, are responsible for part of the observed exchange rate movements. We find that intervention did not affect the realized price volatility of the CAD/USD. These findings are robust to changes in the event definition itself. Repeating the analysis on subsamples according to whether intervention was mechanistic or discretionary yields similar results.

When using intraday intervention and exchange rate data, we find evidence in support of effectiveness when analyzing exchange rate returns (i.e., when focusing on the "direction" and the "smoothing" criteria of success) over the 5- through 120-minute windows. Additionally, we find some evidence that intervention is associated with a reduction of intraday exchange rate volatility, although it appears that the volatility effects are short-lived (only detectable within an hour after the intervention event) and not robust to adjusting for currency co-movements.

The rest of this paper is organized as follows. Section 2 details institutional aspects of BoC intervention. Section 3 describes the data. Section 4 discusses the event study methodology. Section 5 describes the analysis based on daily intervention data. Section 6 reports the findings using high-frequency (intraday) intervention data. Section 7 discusses the findings and section 8 concludes.

2. Institutional Framework of Intervention

Foreign exchange market intervention is conducted by the BoC, acting as agent for the Government of Canada, using the government's holding of foreign exchange reserves in the Exchange Fund Account.⁹ Intervention in the CAD/USD is guided by the Currency Act. Section 17(1) of the Act states that foreign exchange reserves may be used "to aid in the control and protection of the external value of the monetary unit of Canada."¹⁰ From the standpoint of exchange rate intervention, the Act has been interpreted to mean maintaining an orderly market for the CAD by smoothing movements of the exchange rate and providing liquidity to the foreign exchange market when needed. The BoC intervenes in the foreign exchange markets on behalf of the federal government to counter disruptive short-term movements in the CAD/USD; i.e., intervention is aimed at managing the rate of change of the exchange rate, rather than targeting a specific level. This approach is consistent with "leaning against the wind" in the sense that CAD is bought (sold) when the CAD depreciates (appreciates) against the USD. To make sure that intervention does not change the quantity of money in circulation, the BoC sterilizes its purchases and sales of foreign reserves by depositing or withdrawing the same amount of CAD balances from the financial system

⁹ The Exchange Fund Account holds foreign reserves, such as U.S. dollars, Japanese yen, European euros, and other assets like Special Drawing Rights with the International Monetary Fund, and gold.

¹⁰ The Currency Act is available at: <<http://laws.justice.gc.ca/en/C-52/46306.html>>.

on a daily basis. During the 1995 to 1998 period, intervention in the CAD/USD typically took place during North American market hours from 8 a.m. to 4 p.m. EST, but could continue overnight during European market hours.¹¹ Intervention was "passive," with the BoC leaving offers to buy and sell the CAD, rather than hitting bids.

This period under study features two distinct intervention regimes. A rules-based regime, characterized by a mechanical—and therefore predictable—response to exchange rate movements, was in place until April 1995. The BoC determined when to intervene by monitoring a 100-basis point "non-intervention" band. When one end of the non-intervention band was breached, intervention operations (in terms of USD purchases or sales against the CAD) were conducted at pre-set levels of intensity, with intensity measured by the amount of intervention that occurred for each basis-point change in the CAD/USD. The standard amount was \$4 million per basis point. The non-intervention band was dragged or "ratcheted" in the direction that intervention occurred according to the amount and intensity of the most recent intervention operation.¹² Under this mechanical framework, intervention was quite persistent and would continue until the CAD/USD reversed direction and moved back inside the non-intervention band. In case of a highly volatile exchange rate market, the intensity of intervention was increased to \$6 million or \$8 million per basis point, although the timing of intervention continued to be dictated by market movements. Intervention during this period was typically conducted directly with dealers at the major chartered banks, who were instructed to keep the BoC's intervention activity secret, although market participants soon found out when the BoC was "in the market." Under this mechanistic framework,

¹¹ If the currency continued to move in one direction at the end of North American trading hours, the BoC would leave instructions with a European agent, typically the Bank of England, to intervene on the BoC's behalf within pre-set limits.

¹² The end of the non-intervention band that was breached was termed the "active side," and the exchange rate at which intervention would occur was termed the "on-track" position.

intervention resisted all trends, whether based on market fundamentals or technical factors. As a result, the BoC intervened on 40 per cent of business days from 1 January 1995 to 11 April 1995, and more than 70 per cent of business days from 1975 to 1988, as reported by Murray, Zelmer, and Williamson (1990, Table 3).

On 12 April 1995, a revised intervention regime was introduced, designed to increase the effect of intervention by reducing its frequency, increasing its magnitude, allowing more discretion on its timing, and raising its visibility when it occurred. This change followed a major review of the mechanistic intervention regime and reflected the growth of the currency markets as well as the state of the academic literature. As the Bank explained in a letter sent to exchange market participants:

[The] conclusions of this work support the idea that foreign exchange market intervention is most useful when used as a signalling tool. Our analysis of the current intervention techniques we use is that they are not as effective as they could be in this regard. This is largely because the frequency of our intervention tends to reduce the "newsworthiness" of the fact that we are in the market. Also, given the volumes in today's market, the intensity of our current intervention probably adds little in terms of enhancing market liquidity.¹³

The non-intervention band was widened to 140 basis points and was rebased daily around the 4 p.m. North American closing exchange rate. The daily rebasing reduced the frequency of intervention, because the currency would have had to move by 70 basis points in either direction before intervention would continue. This change allowed for moderate trends in the movement of

¹³ Letter from Don Stephenson, Associate Adviser, Bank of Canada, 5 April 1995.

the currency that were not resisted by intervention, and reduced the frequency of intervention to less than 10 per cent of business days in 1996. The visibility of intervention was increased by increasing the standard intensity of intervention to \$8 million per basis point, leading to larger intervention amounts when it occurred. Intervention was primarily conducted through foreign exchange brokers, who were instructed to announce BoC intervention as soon as the first transaction of the day had been completed. The new framework introduced greater discretion, although it maintained elements of the mechanical framework. The wider non-intervention band continued to be dragged up or down intraday in response to each intervention operation. But the timing of intervention could be varied to allow the BoC to intervene earlier and with greater intensity in response to what were believed to be destabilizing movements of the exchange rate. During such turbulent periods, the non-intervention band could be reset at half the distance from its normal setting, allowing the BoC to intervene sooner, and the intensity of intervention could be increased as the situation demanded. A decision to reset the band in this fashion was made by the BoC and authorized by Canada's Department of Finance.

This change in the intervention framework reflected a growing concern that excessive one-way currency movements due to currency speculation could be damaging for the economy, even under a floating exchange rate regime. Such bandwagon behaviour could become self-fulfilling if left unchecked, creating financial uncertainty and complicating the conduct of monetary policy.

In practice, Table 1 shows that intervention remained mechanistic for the rest of 1995 and most of 1996, with few interventions where the timing was discretionary. Over this period, Figure 1 shows that the CAD moved sideways with no strong trends dominating the currency. Beginning in late 1996, the CAD began to depreciate steadily against the USD along with other major currencies. This trend was partly driven by the events in Asia, where currency pressure forced a number of

East Asian countries to float their currencies. The Asian financial crisis continued until the end of 1997, but global foreign exchange markets remained volatile throughout 1998 with the collapse of Long Term Capital Management and the default of Russia on its foreign currency debt in the summer of 1998. As a result, the timing of intervention in the CAD/USD was entirely discretionary from mid-1997 until September 1998, with intervention taking place on one-quarter of the business days in 1997 and 1998. The magnitude of intervention increased as the pace of the devaluation of the CAD increased.

In September 1998, the intervention policy was changed due to the perceived inability of intervention to resist movements in the exchange rate caused by changes in fundamental factors. Canada's current policy is to intervene in foreign exchange markets on a discretionary, rather than a systematic, basis, and only in the most exceptional circumstances. As the BoC's website states:

Intervention might be considered if there were signs of a serious near-term market breakdown (e.g., extreme price volatility with both buyers and sellers increasingly unwilling to transact), indicating a severe lack of liquidity in the Canadian-dollar market. It might also be considered if extreme currency movements seriously threatened the conditions that support sustainable long-term growth of the Canadian economy; and the goal would be to help stabilize the currency and to signal a commitment to back up the intervention with further policy actions, as necessary.¹⁴

The BoC has not intervened in the CAD/USD since September 1998, although it did participate in concerted intervention against the EUR in September 2000, coordinated by the European Central

¹⁴ Details on the current intervention policy are available at: <<http://www.bankofcanada.ca/en/backgrounders/bg-e2.html>>.

Bank. More detail on the evolution of the BoC intervention framework is provided in Chiu (2003), D'Souza (2002), Murray, Zelmer, and McManus (1997), and Murray, Zelmer, and Williamson (1990).

3. Data

This study covers the period January 1995 to September 1998 and employs non-public, high-frequency (intraday) intervention data in the CAD/USD, made available by the BoC. The intervention data represent the population of intervention transactions over this period, and include the date, the time, and the transaction size (in millions of USD) for each intervention transaction.¹⁵

During the full sample period, 2 January 1995 to 30 September 1998, the BoC carried out 1,530 intervention transactions (on a total of 151 intervention days). Of these transactions, 371 (on a total of 40 intervention days) took place during the intervention program that ended on 11 April 1995.¹⁶ The individual intervention transactions ranged in magnitude from USD 2 million to USD 138 million, with an average amount of USD 18 million and a median amount of USD 20 million.¹⁷ On intervention days, an average of 21 transactions occurred, with the number of transactions ranging from a low of one to a high of 83 (on 7 August 1998).

Table 1 provides an overview of the intervention data, with the daily data summarized in Panels A and B and the high-frequency (intraday) data summarized in Panels C and D. Based on the high-

¹⁵ Since the intervention data set is not publicly available, we do not display or describe, in particular, the intervention magnitudes in great detail.

¹⁶ The starting date of the sample is determined by data availability, because the BoC has not maintained records of intraday intervention transactions prior to January 1995.

¹⁷ Individual transaction magnitude may contain limited information, because intervention transactions conducted through foreign exchange brokers were often bundled together to reduce the number of individual trade "tickets." The event study methodology employed in this study does not rely on information regarding transaction size and uses bid/ask rates rather than transaction prices in order to facilitate the investigation of exchange rate movements across different window lengths.

frequency data, 45.4 per cent of intervention transactions were discretionary and the remaining 54.6 per cent of transactions were carried out in accordance with the mechanistic policy framework. Table 1 also shows that the number of interventions that occurred due to a mechanical rebasing of the non-intervention band dominated in 1995, while the number of discretionary interventions increased steadily from 1996 onwards. Additionally, Table 1 shows that the number of purchases and sales were largely balanced in 1995, while the ratio of purchases to sales increased dramatically over the following years.

The analysis employs both daily and intraday data on the CAD/USD, DEM/USD, GBP/USD, and JPY/USD exchange rates. The daily exchange rate data contain quotes recorded at noon (EST) obtained from the Board of Governors of the Federal Reserve. The intraday exchange rate series are purchased from Olsen and Associates. The intraday data provide the spot rate at the end of every 5-minute interval over a 24-hour period for each of the aforementioned exchange rates.¹⁸

Figure 1 shows the evolution of the CAD/USD exchange rate. Figure 2 shows the CAD/USD juxtaposed against an equally weighted basket of the DEM, the GBP, and the JPY vis-à-vis the USD, with all exchange rates indexed to 100 as of the start of January 1995. The CAD appreciated against the USD in early 1995, but then began depreciating from 1997 onwards. The basket of major currencies appreciated more rapidly against the USD in early 1995, but then depreciated during late 1995, with another rapid depreciation in early 1997. The basket of currencies then appreciated sharply in mid-1998.

¹⁸ The bid and offer rates are provided for intervals where an actual trade takes place, while a representative quote is used for other periods. There is little time variation in the bid/ask spreads and the analysis focuses on the bid rates.

4. Methodology

The starting point for an event study is to define the event of interest and to identify the periods over which the asset price is examined (the "event windows").¹⁹ In this context, the event is defined as an episode of intervention days or a cluster of intervention operations. The event windows are the pre-event days or minutes and the post-event days or minutes during which the CAD/USD exchange rate movements are analyzed.

We study intervention at both the daily frequency and at the intraday or high frequency. When focusing on the daily data, an event is defined as a period of days with official intervention in the CAD/USD in one direction (in terms of purchases or sales), interspaced by a fixed maximum number of consecutive business days of no intervention (the "tranquility" period that can be allowed for while still considering the surrounding days of intervention to be part of the same event). Given the structure of the intervention data at hand and following Fatum and Hutchison (2003a, b), we choose a "tranquility" period of five days for our baseline results and vary this number to check the robustness of our results. We study changes in the CAD/USD during pre- and post-event window lengths ranging from 1 to 10 business days.²⁰ When focusing on the high-frequency data, we define an event as a cluster of individual intervention operations in one direction, with at most 30 minutes between transactions. As with the daily analysis, we check the robustness of the definition of an intervention event by varying the length of the "tranquility" time

¹⁹ For a detailed description of the event study methodology applied to the analysis of foreign exchange market intervention, see Fatum (2000) and Fatum and Hutchison (2003a, b).

²⁰ In order to limit the instances when pre- and post-event windows overlap, the window lengths are not expanded beyond 10 days. A small number of events, however, are interspaced such that an event in one direction (e.g., USD sales) is immediately followed by an event in the opposite direction (e.g., USD purchases), thereby leading to overlaps (regardless of the window length) as well as pre- and post-event windows "contaminated" by the preceding or succeeding event. In order to ensure that none of these occurrences impacted our results, the analysis was redone after dropping the potentially problematic events, and the results were unchanged.

period. We study changes in the CAD/USD during pre- and post-event window lengths ranging from 5 to 120 minutes.

As pointed out by, for example, Dominguez and Frankel (1993), there is no convention on what constitutes successful intervention. For this reason, we apply three alternative criteria for success. The first criterion is simply whether the direction of the movement in the exchange rate is the same as the direction in which the BoC was intervening; e.g., does the value of the CAD relative to the USD increase after CAD are purchased? Although the stated objective of the CAD intervention was to maintain orderly market conditions, and not to target a level for the exchange rate, this criterion is standard in studies of foreign exchange intervention (see Fatum 2000 for a discussion). It is also consistent with the way that the non-intervention band operated over the sample period. This measure of success is referred to as the "direction" criterion, and is formally expressed as follows: An event is a success if either

$$\{E_i > 0 \text{ and } \Delta S_{i+} > 0\} \text{ or } \{E_i < 0 \text{ and } \Delta S_{i+} < 0\},$$

where E_i is the total amount of central bank intervention (positive values represent purchases of USD, negative values represent sales of USD) during event i , and ΔS_{i+} is the percentage change in the CAD/USD during the associated post-event window.

As previously noted, the stated motivation for intervention in the CAD is to maintain orderly markets; thus, it may be the case that intervention operations are carried out for the purpose of smoothing exchange rate movements, rather than for affecting the direction of exchange rate movements. The second criterion—the "smoothing" criterion—classifies an event as successful when intervention is associated with a smoothing of the exchange rate movement, as follows:

$$\{\text{the event is a success according to the "direction" criterion}\} \text{ or}$$

$$\{E_i > 0 \text{ and } \Delta S_{i+} > \Delta S_{i-}\} \text{ or } \{E_i < 0 \text{ and } \Delta S_{i+} < \Delta S_{i-}\},$$

where ΔS_{i-} is the CAD/USD change (in per cent) during the associated pre-event window.

The third criterion compares the volatility before and after each event, where volatility is measured by the realized variance of the CAD/USD, as opposed to the implied volatility studied by Beattie and Fillion (1999).²¹ An event is a success according to the "volatility" criterion if

$$\{\sigma_{i+}^2 < \sigma_{i-}^2\},$$

where σ_{i+}^2 (σ_{i-}^2) denotes the realized post-event variance (pre-event variance) of the CAD/USD exchange rate. Note that the direction of intervention does not affect the results, because intervention operations involving either CAD purchases or sales are classified as successful when volatility is lower after the event relative to before the event. For the daily data analysis, we calculate the variance of the CAD/USD over the relevant window length (1 through 10 days), using the 5-minute high-frequency exchange rate data. For the high-frequency analysis, we calculate the variance of the exchange rate during the 30, 60, 90, and 120 minutes preceding and succeeding each event, and compare the volatility patterns before and after in the same fashion as with the daily data volatility analysis.

Eun and Lai (2004) document systematic co-movement patterns across several currencies, in particular vis-à-vis the USD, and, to a lesser extent vis-à-vis the EUR. They find evidence that currency co-movement is significantly driven by "the competitive influence" of major currencies

²¹ In practice, the BoC monitored changes in the level of the CAD/USD and did not monitor option markets.

on minor ones.²² Currency co-movement is potentially important to the analysis of the effectiveness of intervention, especially since we focus on unilateral intervention conducted in a small, open economy aimed at managing a minor currency vis-à-vis a major currency. For example, if the CAD appreciates against the USD following a CAD purchase intervention, this event will appear effective according to the “direction” criterion. If the USD is depreciating against other currencies in general, however, there is little reason to believe that the USD depreciation can be ascribed to the unilateral BoC intervention. In order to address this concern, we carry out both the daily data and the high-frequency analysis of effectiveness using a “filtered” CAD/USD exchange rate as well as using the “raw” CAD/USD rate. The filtered CAD/USD is calculated as the difference between the percentage change in the CAD/USD and the percentage change in an equal-weighted basket of the GBP/USD, DEM/USD, and JPY/USD exchange rates.²³ Figure 2 shows the evolution of the “raw” CAD/USD against the equally weighted basket of the DEM/USD, GBP/USD, and JPY/USD exchange rates, where both are indexed to 100 as of the start of January 1995.

We use three formal tests to determine the statistical significance of our results. The first is the non-parametric sign test. It verifies whether the observed number of successes, based on the “direction,” “smoothing,” or “volatility” criteria following intervention events, are random or systematic. With reference to the “direction” criterion for success, the null hypothesis is that the probability of observing a positive value (success) is the same as that of observing a negative value (no success), hence the underlying probability parameter is 0.5. In other words, the random variable X (equal to the number of positive values, or “successes”) among n sample observations has a binomial

²² As Eun and Lai (2004) point out, despite the vast research in co-movement of other asset prices, such as bonds and stocks, the potentially highly important issue of currency co-movement has not been given much attention in the academic literature.

²³ In both analyses, we vary the weights when calculating the filtered exchange rate as additional robustness checks, without detecting qualitatively different results. For brevity, we report only the results based on equal weights.

distribution with $\mu = 0.5$. A significant sign test indicates that the observed number of successes is not a random finding attributable to the equal probability of appreciation or depreciation. For details on this test in event studies, see MacKinlay (1997).²⁴

The second test is the non-parametric rank test. It is applied only to the high-frequency analysis; the smaller number of events in the daily data analysis precludes this test. The third test is the matched sample (difference-in-means) test. The matched sample test is associated with the "smoothing" criterion, since it indicates, at the minimum, smaller post-event CAD depreciation or appreciation, and it is applied to both the high-frequency and the daily data analysis. Since both additional tests confirm the results based on the sign test, for brevity we focus on the results from the first test.²⁵

5. Results of the Daily Data Analysis

Table 2 provides details on intervention episodes from 1995 to 1998 when events are classified using daily data, 2-day pre- and post-event windows, and a maximum 5-day "tranquility" period. The second column of the table shows the direction of the intervention (in terms of purchases (P) or sales (S) of USD) for each event. The final four columns provide details on the behaviour of the CAD/USD in terms of the average daily percentage change and volatility during the pre- and post-event windows. By comparing the direction of each intervention event (column 2) with the associated post-event exchange rate (column 4), success according to the "direction" criterion is assessed. Similarly, a comparison of direction of each intervention event with the average daily

²⁴ See Fatum (2000) for a discussion of the choice of probability parameters associated with the "direction" and the "smoothing" criteria for success.

²⁵ For details on the rank test in event studies, see Campbell and Wasley (1993) and MacKinlay (1997). See, for example, Ben-Horim and Levy (1984, 458) for details on the matched sample test and Fatum and Hutchison (2003a, b) for applications.

percentage change in CAD/USD before (column 3) and after each event (column 4) addresses the issue of success according to the "smoothing" criterion. Finally, success according to the "volatility" criterion is assessed by comparing pre-event volatility (column 5) with post-event volatility (column 6).

We identify 58 separate intervention events over the 1995 to 1998 period, of which 27 lasted for multiple days. Table 2 shows that the direction of the change in the exchange rate during the post-event window was consistent with the direction of the associated intervention in 28 events and, accordingly, inconsistent in 30 events. Put differently, 28 of the 58 events were successful according to the "direction" criterion; 54 of the 58 events were successful according to the "smoothing" criterion. Comparing the 2-day pre-event volatility with the 2-day post-event volatility, 26 events were associated with decreased post-event volatility and 32 events were associated with increased post-event volatility. The following sections report the results of the formal tests.

5.1 Direction results

Figure 3 shows the results of the sign test based on the "direction" criterion with the underlying probability parameter of 0.50. Each column represents the number of successes based on a different window length, with pre- and post-event windows ranging from 1 to 10 business days. The 2-day pre- and post-event windows shown in Table 2 are associated with the second column in Figure 3. In Figures 3(a)-(f), the horizontal line shows the number of successes necessary to reject a random

outcome at the 95 per cent significance level.²⁶ Figures 3(a)-(c) summarize the findings based on all 58 events for the "raw" CAD/USD exchange rate, and Figures 3(d)-(f) summarize the findings based on the same 58 events for the "filtered" CAD/USD rate that controls for currency co-movements against the USD. Figure 3(a) shows evidence in support of effectiveness at window lengths of 3 through 7 days and again at 9 days, as the associated bars reach (or exceed) the horizontal line (at 36 successes out of 58). Figure 3(d) shows evidence in support of effectiveness at window lengths of 3, 4, and 8 days. Clearly, adjusting for the co-movements of major currencies against the USD weakens the results in support of effectiveness, yet we still reject the null hypothesis that the observed number of successes is random across all window lengths.

As noted earlier, the sample period under study is of particular interest, because it comprises two intervention regimes: a mechanistic regime through mid-April 1995 and a mixed regime featuring both mechanistic and discretionary intervention from mid-April 1995 to September 1998. Mechanistic intervention operations, whether carried out under the first or the second regime, are likely to have been anticipated by market participants, whereas discretionary intervention operations carried out under the second regime had the potential of surprising the markets and, therefore, have a stronger impact (see Murray, Zelmer, and McManus 1997). In order to investigate this possibility, we redo the analysis on subsamples of events associated with mechanistic intervention and events associated with discretionary intervention separately.²⁷

²⁶ For ease of exposition, only the horizontal bar associated with the 95 per cent significance level is shown. Given the limited number of daily events, effectiveness assessed according to the 90 per cent significance level, instead, does not dramatically increase the described support for effectiveness.

²⁷ Two events contain both mechanistic and discretionary intervention transactions, and these are classified as mechanistic events, for convenience.

Figures 3(b) and (e) show the results of the analysis of the 43 mechanistic intervention events using the "raw" and the "filtered" CAD/USD exchange rate, respectively. Based on the "raw" CAD/USD rate, five of the bars shown in Figure 3(b) reach (or exceed) the horizontal line (at 28 successes out of 43), which suggests that intervention is systematically associated with success according to the "direction" criterion. Focusing instead on Figure 3(e) and the "filtered" rate, significance at the 95 per cent level is found only at the 4-day window length. Figures 3(c) and (f) show the analysis of the 15 discretionary events. We find that none of the bars reaches (or exceeds) the horizontal line (at 12 successes out of 15), potentially due to the test's low degrees of freedom. Therefore, we find no significant evidence in support of effectiveness when analyzing discretionary intervention events.

5.2 Smoothing results

Figure 4 shows the results based on the "smoothing" criterion where the sign test is based on an underlying probability parameter of 0.75 for pre- and post-event window lengths ranging from 1 to 10 days. Figures 4(a) and (d) summarize the findings based on all 58 events for the "raw" and the "filtered" CAD/USD rate, respectively. Figure 4(a) shows that the observed number of successes is statistically significant at the 95 per cent level (at 50 or more successes out of 58) for window lengths of 1, 2, 3, 6, and 9 days. When analyzing the "filtered" rate, the observed number of successes is not significant at any window length, which suggests that currency co-movements against the USD do matter for our results. Figures 4(b) and (e) show the results based on the 43 mechanistic events, and Figures 4(c) and (f) show the results based on the 15 discretionary events. The subsample results are similar to those based on the full sample, showing some support for success according to "smoothing" when using the "raw" CAD/USD rate; no support for success is found when using the "filtered" CAD/USD rate.

5.3 Volatility results

Figure 5 shows the results for the comparison of pre-event versus post-event volatility for pre- and post-event window lengths ranging from 1 to 10 days. The sign test determines whether the observed number of events associated with decreased CAD/USD volatility is random or systematically associated with intervention events. The test has an underlying probability parameter of 0.50; thus, the horizontal 95 per cent lines for Figures 5(a)-(f) are (pairwise) identical to the significance lines for the sign test results of "direction," as Figures 3(a)-(f) show.

Figures 5(a)-(f) report the results of these tests. Despite engaging in intervention designed to maintain orderly markets for the CAD/USD, there is no support for the hypothesis that volatility decreases following an intervention episode. Figures 5(a)-(c) show that the volatility of the "raw" CAD/USD does not systematically decrease, whether investigating all events together or the subsamples of mechanistic and discretionary interventions separately. As Figures 5(d)-(f) show, netting out the impact of currency co-movements against the USD does not change this conclusion. In sum, there are no instances of window lengths where the associated number of decreased post-event volatility reaches the level of statistical significance.

Because some studies find that intervention is systematically associated with increased volatility, we also test this possibility (results not shown, for brevity).²⁸ We find evidence in support of increased volatility only when we analyze the full sample and the "raw" CAD/USD rate, and only for window lengths of 1 and 5 days. For all other window lengths, we accept the null hypothesis that the observed number of events associated with increased post-event volatility is random. When

²⁸ See King (2003) for details on these studies.

the CAD/USD rate is adjusted for currency co-movements against the USD, we reject the null hypothesis only at the 1-day window length. Additionally, when analyzing the subsamples of mechanistic and discretionary intervention events separately, we reject the existence of a systematic link between intervention and increased volatility for all window lengths except one. In sum, our findings do not support the view that intervention is associated with increased exchange rate volatility when analyzing the daily data.

5.4 Monetary policy changes and USD intervention by other central banks

As pointed out by Fatum and Hutchison (2003a) and others, the event study methodology assumes that intervention defines the event and is not systematically related to other relevant economic news, such as monetary policy changes or USD intervention by other central banks. In principle, this is a concern in all event studies, but it is of particular concern in the context of our daily data analysis, where a large number of intervention episodes last for several days.

In order to address this concern, we redo the analysis on subsamples of events that do not coincide with monetary policy changes conducted by either the BoC or the U.S. Federal Reserve. Table 3 shows that there are only 12 days over the period under study when BoC intervention occurred on a day when the BoC changed the target for the overnight rate. There are no cases of CAD/USD intervention coinciding with changes in U.S. monetary policy.²⁹ Although the power of the tests is reduced, the daily data results described above are robust to the exclusion of these 12 events.

²⁹ During our sample period, there were 28 days when only the Canadian overnight rate target changed, 2 days when only the target for the federal funds rate changed, and 4 days when monetary policy in both countries changed on the same day.

Intervention in the DEM/USD or the JPY/USD by other major central banks coincides with 4 days of BoC intervention. Dropping these 4 events from the analysis does not impact our results.³⁰

Sarno and Taylor (2001, 850) state that "[Intervention] policies which are inconsistent with the underlying stance of monetary and fiscal policy are doomed to ultimate failure." When intervention is inconsistent with the direction of monetary policy, it may be viewed as unsustainable and lacking credibility. We checked whether intervention in the CAD was consistent with the direction of monetary policy by comparing the direction of intervention with the direction of changes in monetary policy over the same period. When monetary policy was tightening, purchases of the CAD would be consistent, whereas sales of the CAD would be inconsistent. When monetary policy was easing, the reverse would be true. We find that there was no systematic pattern between intervention in the CAD and Canadian monetary policy, which suggests that the intervention in the CAD was not designed to target a level for the currency. See King (2003) for a discussion of different intervention strategies and objectives.

6. Results of the High-Frequency (Intraday) Data Analysis

It is possible that some of the impact of intervention in the CAD/USD market is so short-lived that it cannot be detected using daily data. In order to investigate this possibility, this section analyzes intervention using a unique data set of high-frequency, official intervention data provided by the BoC, along with high-frequency exchange rate data (with quotes at a 5-minute frequency, 24 hours per day) obtained from Olsen and Associates. We apply the event study approach of the previous section to the analysis of the high-frequency intervention data, defining an event as a cluster of

³⁰ As a further robustness check, the event definition was changed to allow for no more than 3 (instead of 5) days of "tranquility," and the analysis was redone. This change of event definition affected only 5 events and did not affect the results.

individual intervention transactions in one direction, interspaced by at most 30 minutes of no intervention.³¹

Using the high-frequency data and the 30-minute event definition, the BoC intervened in the CAD/USD exchange rate market on 321 separate events, 270 of which occurred within market hours (between 8 a.m. and 4 p.m. EST). While the timing of intervention operations carried out within North American market hours is known, this is not the case for intervention operations that occurred outside of market hours. In order to make the most of our knowledge of the timing of intervention operations, we focus our high-frequency analysis on the 270 events that took place within market hours.

6.1 Direction results

Figure 6 shows the results from the sign test based on the "direction" criterion with the underlying probability parameter of 0.50 across all window lengths (5 through 120 minutes).³² For Figures 6(a)-(f), the horizontal line shows the number of successes necessary to reject randomness at the 95 per cent significance level. Figure 6(a) summarizes the findings based on all 270 events and the "raw" CAD/USD exchange rate, and Figure 6(d) summarizes the findings based on the same 270 events and the "filtered" CAD/USD rate.

All the bars in Figure 6(a) reach or exceed the horizontal line (at 150 successes out of 270); thus, the null hypothesis that the observed number of successes is random is rejected (separately) for

³¹ As a robustness check, we changed the event definition and redid the analysis of section 6. Specifically, we defined an event as a cluster of individual intervention operations in one direction, interspaced by at most 60 (instead of 30) minutes of no intervention operations. Using this slightly altered event definition, 220 (instead of 270) within-market-hours events are identified. These changes yielded qualitatively identical results.

³² Due to the non-public nature of the BoC intervention data, the intervention volumes and the exact timing of events are not shown.

each window length. Accordingly, the results shown in Figure 6(a) provide strong evidence that BoC intervention is associated in a highly significant and systematic way with intraday movements in the CAD/USD exchange rate. This finding conforms with the BoC consistently applying the non-intervention framework discussed in section 2.

Furthermore, it is interesting to note that the impact on the CAD/USD persists to the end of the 2-hour post-event window, which suggests that the impact of intervention is longer than documented in other high-frequency studies.

Turning to the analysis of the "filtered" exchange rate and Figure 6(d), the findings of significance at the 95 per cent level are repeated for window lengths of one hour or less. For both Figures 6(a) and (d), it is the case that the significance levels tend to drop as the window length increases. This finding suggests that part of the duration effects found when analyzing the "raw" exchange rate may be attributed to general movements in the USD, and not to intervention itself.

As noted earlier, the sample period under study is of particular interest because it comprises two different intervention regimes, the first characterized by mechanistic intervention and the second characterized by both mechanistic and discretionary intervention. In order to investigate whether mechanistic and discretionary intervention events affect the market differently, the analysis is redone separately on the subsample of events associated with mechanistic intervention, and redone separately on the subsample of events associated with discretionary intervention.³³

³³ Events containing both mechanistic and discretionary intervention transactions are classified as discretionary. Alternatively, dropping these "mixed" events from the analysis does not affect the results.

Figures 6(b) and (c) show the results of the analysis of the 145 mechanistic events using the "raw" CAD/USD and the "filtered" CAD/USD exchange rates, respectively. Both figures repeat the patterns displayed for the full samples; i.e., when focusing on the "raw" exchange rate, intervention is significant at the 95 per cent level across all window lengths, whereas intervention is significant, at a minimum, at the 90 per cent level when focusing on the "filtered" exchange rate (not shown).

Figures 6(c) and (f) show the results based on the discretionary events. Again, for almost all window lengths of one hour or less, it is the case that the null hypothesis of randomness is rejected at the 95 per cent significance level (at 73 successes or more out of 125). Somewhat surprisingly, there is no indication that discretionary intervention is, on average, associated with stronger effects than mechanistic intervention. In fact, when focusing on the window lengths that are longer than one hour, there is not a single instance of significant effects of discretionary intervention at the 95 per cent level, and this is in contrast to the findings based on the subsample of only mechanistic events.³⁴ The previously observed pattern of lowered significance levels as the window lengths are expanded is repeated.

In sum, the analysis based on the "direction" criterion of success shows that BoC intervention is significantly associated with intraday movements in the CAD/USD exchange rate and that the effects of intervention appear to be strongest when window lengths of one hour or less are considered. Furthermore, the results imply that BoC intervention has a very similar intraday impact

³⁴ It is noteworthy that the difference in sample sizes when comparing significance across mechanistic and discretionary events leads to different degrees of freedom of the sign test and, furthermore, that the success-to-failure ratio is very similar across the two subsamples.

on the CAD/USD exchange rate regardless of whether the intervention events are rules-based or discretionary. These results are consistent with the BoC following the intervention strategy described in section 2, with intervention continuing until the currency reversed direction.

6.2 Smoothing results

Figure 7 shows the results based on the "smoothing" criterion and the sign test with the underlying probability parameter of 0.75 across all window lengths. Figures 7(a) and (d) summarize the findings based on all 270 events and the "raw" CAD/USD and the "filtered" CAD/USD exchange rate, respectively. The observed number of successes is, of course, higher than the observed number of successes according to the "direction" criterion, by construction of the "smoothing" criterion that embodies the "direction" criterion; similarly, so is the number of successes necessary to reject the null hypothesis of randomness. Both Figures 7(a) and (d) show patterns very similar to the corresponding "direction" figures (Figures 6(a) and (d)), and repeat the findings of significance at the 95 per cent level for all window lengths when focusing on the "raw" exchange rate measure. The longer window lengths for both the "raw" and the "filtered" rate are generally associated with significance at the 90 per cent level or higher.

Figures 7(b) and (e) (Figures 7(c) and (f)) show the results based on the 145 (125) mechanistic (discretionary) events; the findings are very similar to those based on the "direction" criterion. In particular, there is again no indication whatsoever that discretionary intervention is more effective than mechanistic intervention. Furthermore, Figure 7(f) shows that there are no significant effects of discretionary intervention at the 95 per cent level when focusing on the "filtered" exchange rate.

For all these results, the effects are marginally weaker when removing general movements against the USD.

6.3 Volatility results

Figure 8 shows the results of the comparison of pre-event versus post-event volatility across window lengths of 30, 60, 90, and 120 minutes. In this context, the sign test determines whether the observed number of events associated with decreased CAD/USD volatility is random or systematically associated with intervention events. Consistent with the volatility analysis in Fatum and Hutchison (2003a), the test has an underlying probability parameter of 0.50. Therefore, the horizontal 95 per cent significance lines for Figures 8(a)-(f) are (pairwise) identical to the significance lines for the sign test results of the "direction" criterion, as shown in Figures 6(a)-(f).

Focusing first on the analysis using the "raw" exchange rate, Figures 8(a)-(c) show that the number of events associated with decreased post-event volatility is high enough to reject randomness at conventional significance levels when 30- and 60-minute window lengths are investigated, while the number of successes according to the "volatility" criterion is too small to question randomness when the window lengths are expanded. In other words, the volatility effects of intervention are significant but short-lived, in that the effects are detectable only when comparing exchange rate movements within one hour before and after the events. This appears to be the case regardless of whether the subsamples of mechanistic and discretionary intervention are analyzed separately or whether all the events are analyzed jointly.

Turning to the "filtered" exchange rate and the results shown in Figures 8(d)-(f), the pattern regarding lower significance levels as the window lengths are expanded is repeated. For the analysis using the "filtered" exchange rate, however, none of the window lengths is associated in a significant and systematic way with intraday CAD/USD exchange rate volatility (none of the bars reaches the horizontal 95 per cent significance line), which implies that the effects of intervention

on volatility patterns within the first two hours around the described events are less robust than the effects of intervention on "discretion" and "smoothing."³⁵

7. Discussion of Results

Given that CAD intervention was not designed to target a level of the currency, the finding that intervention is associated with a systematic change in the direction of the CAD/USD may seem surprising. These results, however, are consistent with the operation of the intervention framework, where intervention might continue over days until the CAD/USD reversed direction.

This effect of BoC intervention may reflect how markets perceived the "signal" communicated by intervention. For part of the period under study, monetary policy was being used explicitly by the BoC to rebalance monetary conditions in response to movements in the exchange rate. A large movement in the exchange rate would change the level of monetary conditions in the economy, and intervention could send confusing signals to market participants about the future direction of monetary policy. Such a situation occurred in late 1996, when the appreciation of the CAD caused a dramatic tightening of monetary conditions at a time when the BoC was easing monetary policy. The BoC responded by cutting its overnight rate target on three occasions in October and November 1996 to rebalance monetary conditions.³⁶ The BoC—having stayed out of the currency markets during this period—intervened to sell CAD on 5 November 1996, shortly before a rate cut was announced on 8 November. The timing of these events may have led foreign market

³⁵ As noted previously, some studies find that intervention is systematically associated with increased volatility; therefore, our analysis also tested for this possibility. However, the observed number of events associated with increased volatility is random across all window lengths (30, 60, 90, and 120 minutes).

³⁶ The BoC took the exchange rate as given and responded with changes in the overnight interest rate to rebalance monetary conditions, with reference to a monetary conditions index (MCI).

participants to believe that intervention was being used as a signal of future monetary policy changes. When the BoC next intervened to sell Canadian dollars, it immediately contacted market participants to explain that the intervention had no monetary policy implications.

In short, financial market participants may have perceived that intervention was being used as a signal of future monetary policy changes, despite the fact that BoC intervention was not designed to send this signal. This episode may suggest that intervention designed to maintain orderly markets could create uncertainty about monetary policy in a small, open economy. It also reinforces the importance of distinguishing between sterilized intervention operations designed to manage the exchange rate, and unsterilized money market operations involved in the conduct of monetary policy.

8. Conclusion

This paper investigates the effectiveness of sterilized intervention in the CAD/USD exchange rate from 1995 to 1998 using official intervention data provided by the BoC. The data set is unique, because it consists of high-frequency (intraday) data with information on the timing and magnitude of each intervention operation at the transaction level. The time period studied covers two distinct intervention regimes—an earlier mechanistic regime where intervention was frequent and widely anticipated, and a revised regime that introduced more discretion on the timing of intervention, increased the intensity, and heightened the visibility.

We use an event study framework to analyze the impact of intervention on exchange rates. Given that we are not studying a major currency, and that the CAD may therefore be affected by large movements of the USD versus other major currencies, we check the robustness of our results by controlling for currency co-movements using a “filtered” CAD/USD that nets out movements in a basket of the DEM/USD, JPY/USD, and GBP/USD exchange rates.

We find that intervention did not have a systematic impact on the volatility of the CAD/USD when aggregating intervention operations at the daily level. We find some evidence that intervention was systematically associated with both a change in the direction and a smoothing of the CAD/USD at this frequency. In particular, intervention had the desired effect of smoothing the exchange rate over periods of 1 to 3 business days following intervention events, whereas the CAD/USD would move in the same direction that intervention occurred over periods of 3 to 9 business days following intervention. These effects are weakened when controlling for currency co-movements against the USD, suggesting that controlling for currency co-movements is important when assessing the effectiveness of intervention.

Consistent with the results of Payne and Vitale (2003), we find evidence in support of effectiveness when analyzing intraday exchange rate returns (i.e., when focusing on the "direction" and the "smoothing" criteria of success) over the 5- through 120-minute windows. Additionally, we find some evidence that intervention is associated with a relatively short-lived reduction of exchange rate volatility.

Contrasting the results of the analysis of rules-based events with the results of the analysis of the discretionary events does not suggest that discretionary intervention is more effective than rules-based intervention.

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Table 1: Canadian Dollar Intervention Data, January 1995 – September 1998

Panel A: Overview of daily data

	Mechanistic	Discretionary	Total	Per cent
Buy CAD	41	57	98	64.9
Sell CAD	52	1	53	35.1
Total	93	58	151	100.0
Per cent	61.6	38.4	100.0	

Panel B: Frequency of daily intervention

Year	No. of mechanistic intervention	No. of discretionary intervention	No. of buy CAD	No. of sell CAD
1995	67	0	26	41
1996	9	4	9	4
1997	17	20	30	7
1998	0	34	33	1
Total	93	58	98	53

Panel C: Overview of intraday (high-frequency) data

	Mechanistic	Discretionary	Total	Per cent
Buy CAD	444	688	1,132	74.0
Sell CAD	392	6	398	26.0
Total	836	694	1,530	100.0
Per cent	54.6	45.4	100.0	

Panel D: Frequency of intraday (high-frequency) intervention

Year	Per cent of total	No. of mechanical	No. of discretionary	No. of buy CAD	No. of sell CAD
1995	39.9	611	0	321	290
1996	5.9	41	49	77	13
1997	23.3	184	173	268	89
1998	30.8	0	472	466	6
Total	100.0	836	694	1,132	398

Table 2: Overview of Intervention Events, January 1995 to September 1998

(1)	(2)	(3)	(4)	(5)	(6)
Event	Direction: Purchase (P) or Sale (S) of USD	Avg. daily % change in CAD/USD over preceding 2 days ¹	Avg. daily % change in CAD/USD over subsequent 2 days ¹	Volatility in CAD/USD over preceding 2 days ²	Volatility in CAD/USD over subsequent 2 days ²
1	S	0.1956	-0.3181	0.000061	0.000140
2	P	-0.3181	-0.1254	0.000199	0.000247
3	S	0.3723	-0.2143	0.000202	0.000083
4	P	-0.2143	0.0000	0.000162	0.000306
5	S	0.0000	-0.2937	0.000294	0.000369
6	P	-0.3230	0.2788	0.000308	0.000105
7	S	0.0705	-0.5635	0.000258	0.000055
8	P	-0.2023	-0.0918	0.000055	0.000267
9	P	-0.3877	0.1399	0.000232	0.000081
10	S	0.2649	0.0110	0.000103	0.000219
11	P	-0.2620	0.2174	0.000224	0.000148
12	P	-0.2310	0.1365	0.000167	0.000274
13	S	0.1876	-0.1143	0.000274	0.000196
14	S	0.3176	-0.4606	0.000029	0.000254
15	P	-0.4606	-0.0294	0.000247	0.000226
16	P	-0.4606	-0.1196	0.000220	0.000262
17	S	0.1601	-0.2127	0.000054	0.000257
18	P	-0.1860	0.2621	0.000223	0.000260
19	S	0.4037	-0.0732	0.000232	0.000448
20	P	-0.1468	0.3219	0.000166	0.000248
21	S	0.4158	-0.1106	0.000242	0.000337
22	S	0.3562	0.0653	0.000272	0.000242
23	P	-0.5507	-0.0699	0.000265	0.000218
24	P	-0.1031	-0.1329	0.000142	0.000276
25	S	0.2107	-0.1706	0.000231	0.000088
26	P	-0.4134	0.2113	0.000264	0.000243
27	S	0.2212	0.1122	0.000275	0.000276
28	S	0.1469	0.0330	0.000233	0.000238
29	S	0.0219	-0.0036	0.000216	0.000264
30	S	0.2668	0.0438	0.000210	0.000101
31	P	-0.1426	-0.0073	0.000244	0.000192
32	P	-0.0675	-0.0300	0.000121	0.000245
33	S	0.1744	-0.0958	0.000162	0.000087

(continued)

Table 2: Overview of Intervention Events, January 1995 to September 1998 (concluded)

(1)	(2)	(3)	(4)	(5)	(6)
Event	Direction: Purchase (P) or Sale (S) of USD	Avg. daily % change in CAD/USD over preceding 2 days ¹	Avg. daily % change in CAD/USD over subsequent 2 days ¹	Volatility in CAD/USD over preceding 2 days ²	Volatility in CAD/USD over subsequent 2 days ²
34	P	-0.6338	-0.0821	0.000196	0.000305
35	S	0.1193	0.0967	0.000269	0.000198
36	S	0.1355	0.0365	0.000260	0.000259
37	S	0.2227	0.3481	0.000114	0.000268
38	S	0.0792	0.0108	0.000240	0.000178
39	P	-0.3022	-0.2969	0.000196	0.000190
40	P	-0.2574	-0.1202	0.000210	0.000320
41	S	0.2604	-0.0217	0.000155	0.000276
42	S	0.2890	0.0793	0.000242	0.000065
43	S	0.1009	-0.4813	0.000234	0.000413
44	S	0.1720	0.0143	0.000192	0.000199
45	S	0.3076	-0.0355	0.000083	0.000190
46	S	0.3193	-0.0178	0.000240	0.000086
47	S	0.1228	-0.2292	0.000255	0.000210
48	S	0.0597	-0.3849	0.000183	0.000230
49	S	0.1922	0.0245	0.000194	0.000267
50	P	-0.1473	0.3725	0.000267	0.000037
51	S	0.0243	-0.1723	0.000215	0.000097
52	S	0.2584	0.2605	0.000117	0.000239
53	S	0.3911	0.2068	0.000231	0.000230
54	S	0.1821	0.0240	0.000122	0.000207
55	S	0.2624	0.0782	0.000214	0.000185
56	S	0.2154	0.1176	0.000179	0.000219
57	S	0.2415	-1.1700	0.000243	0.000711
58	S	-0.4189	0.0393	0.000414	0.000352

1. Average daily percentage change in the daily CAD/USD over the two business days prior to (after) first (last) day of the event.

2. Volatility of the percentage change in the high-frequency CAD/USD over the two business days prior to (after) the first (last) day of the event.

Table 3: Intervention Coinciding with Changes in Canadian Monetary Policy

Date	Change in overnight rate target	Overnight rate target after change	Direction: Purchase (P) or Sale (S) of USD
10-Jan-95	0.50	6.00	S
12-Jan-95	0.50	6.50	S
17-Jan-95	0.50	7.00	S
16-Feb-95	0.50	8.00	S
10-Jul-95	-0.25	6.75	P
28-Aug-95	-0.25	6.25	P
31-Oct-95	-0.25	6.00	P
25-Jan-96	-0.25	5.50	S
18-Apr-96	-0.25	4.75	S
12-Dec-97	0.50	4.25	S
30-Jan-98	0.50	4.75	S
27-Aug-98	1.00	5.75	S

Note: There was no intervention coinciding with changes in U.S. monetary policy over this period.

Figure 1: Canadian Dollar Exchange Rate versus U.S. Dollar

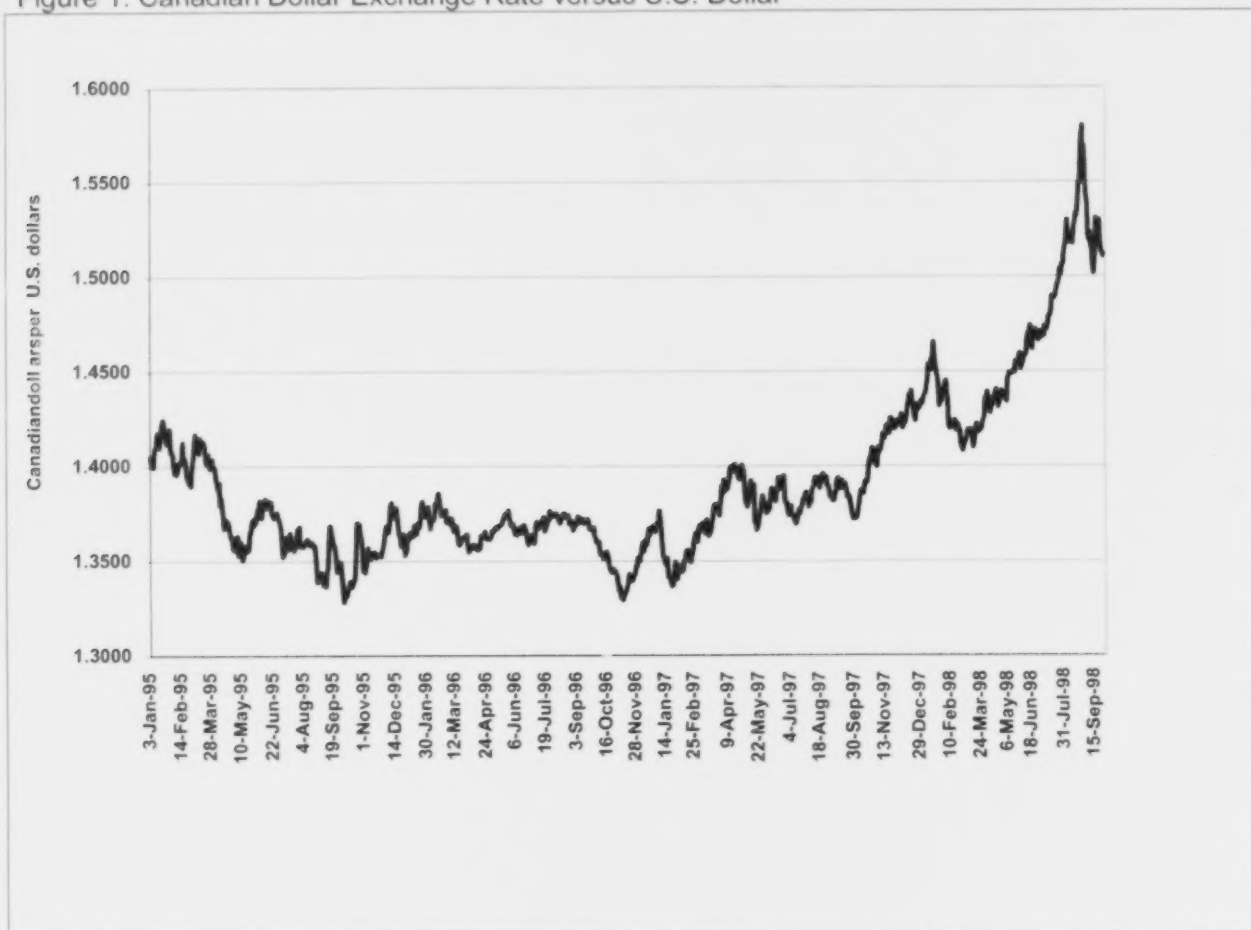


Figure 2: Index of Canadian Dollar vs. Net Change in Basket of German Deutsche Mark, Japanese Yen, and U.K. Pound Sterling (1 January 1995 = 100)

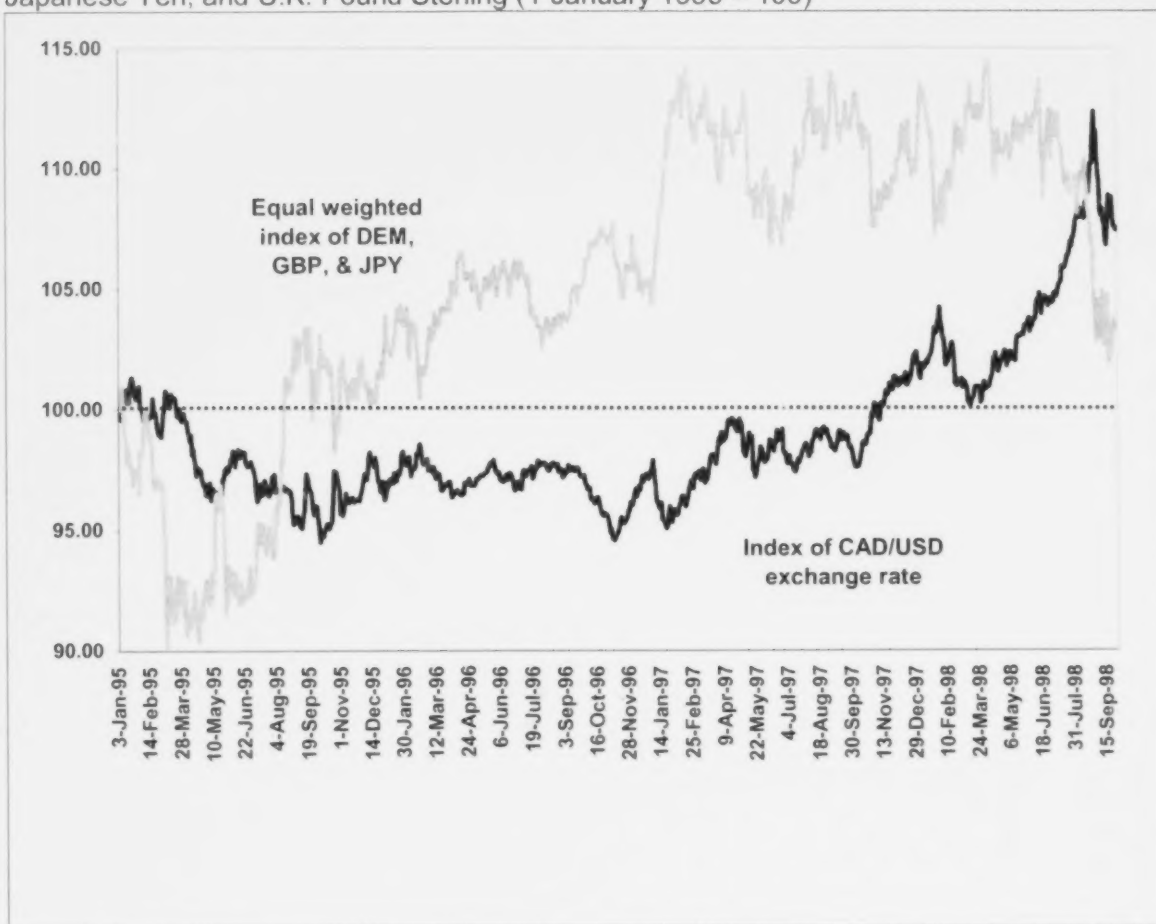


Figure 3: Success of Intervention Using Daily Data — Direction Criterion

This figure shows the results for the sign test based on the “direction” criterion with the underlying probability parameter of 0.50. Intervention is a success when the CAD/USD moves in the direction of intervention after the event. Each column represents the number of successes based on a different window length, ranging from 1 to 10 business days. For all Figures 3(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 3(a)-(c) summarize the findings using the “raw” CAD/USD, and Figures 3(d)-(f) summarize the findings using the “filtered” CAD/USD.

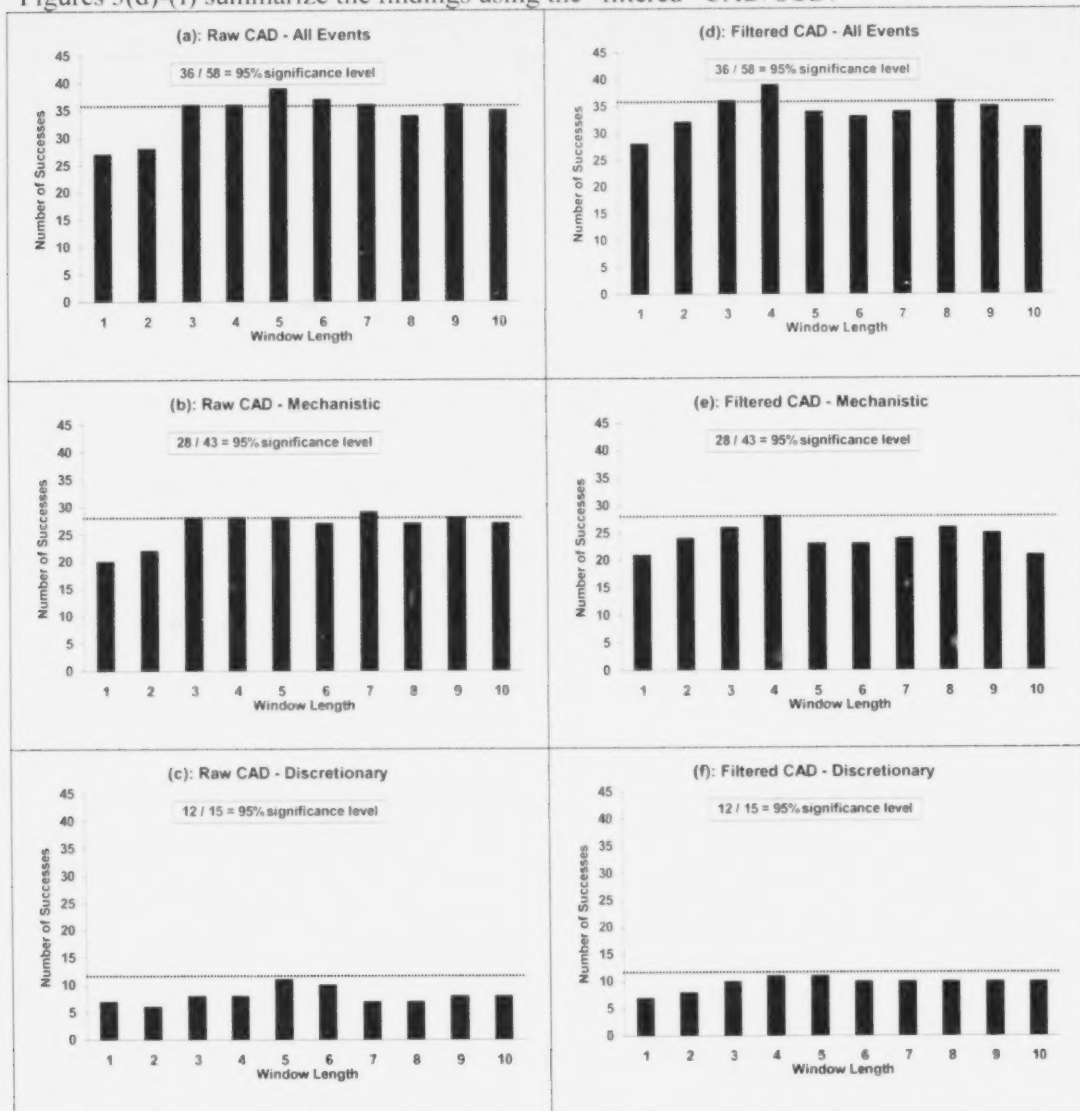


Figure 4: Success of Intervention Using Daily Data — Smoothing Criterion

This figure shows the results for the sign test based on the “smoothing” criterion with the underlying probability parameter of 0.75. Intervention is a success when the CAD/USD changes direction due to intervention, or when the rate of change of the CAD/USD is slower following intervention. Each column represents the number of successes based on a different window length, ranging from 1 to 10 business days. For all Figures 4(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 4(a)-(c) summarize the findings using the “raw” CAD/USD, and Figures 4(d)-(f) summarize the findings using the “filtered” CAD/USD.

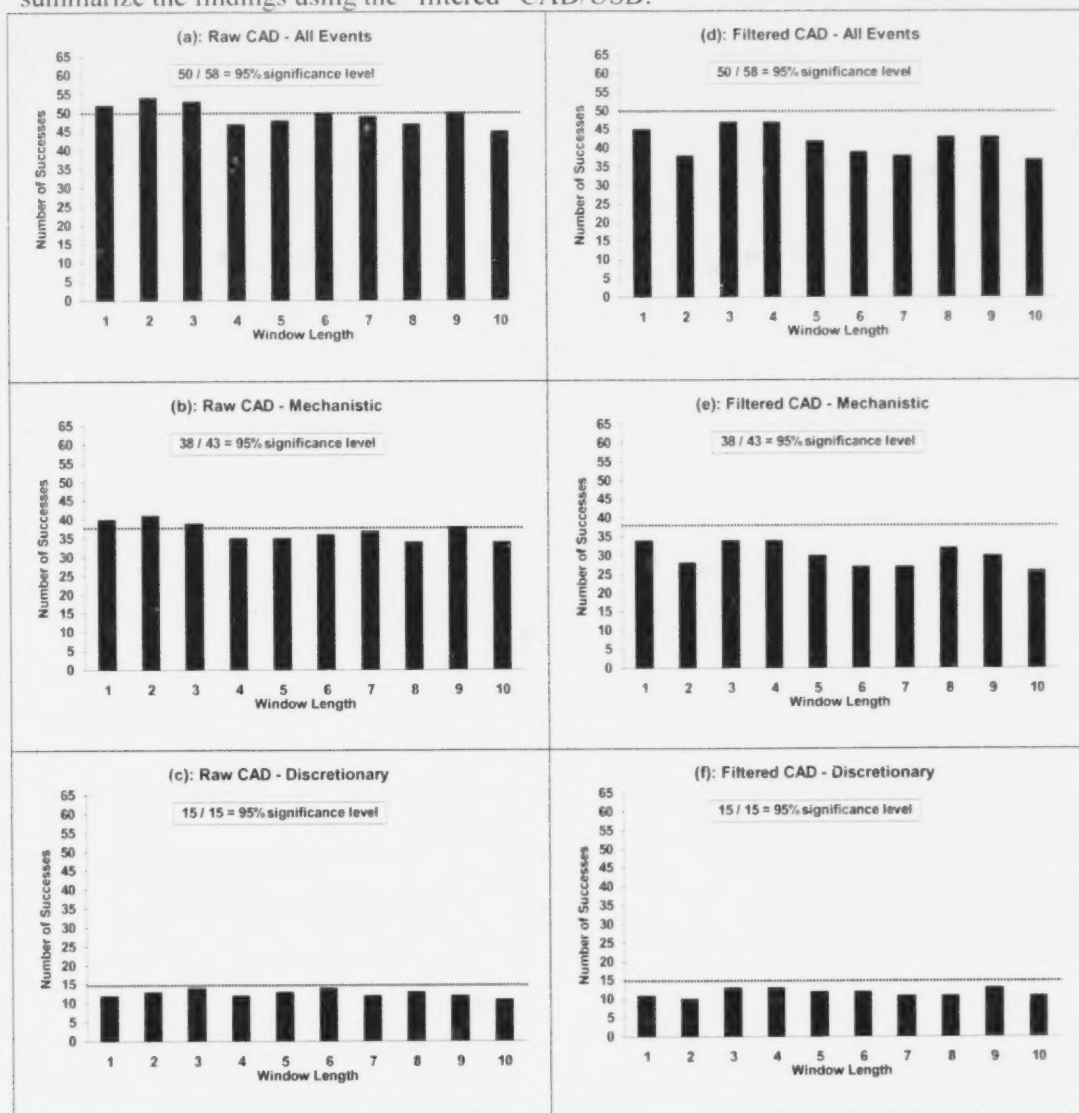


Figure 5: Success of Intervention Using Daily Data — Volatility Criterion

This figure shows the results for the sign test based on the “volatility” criterion with the underlying probability parameter of 0.50. Intervention is a success when volatility decreases from before to after the event. Each column represents the number of successes based on a different window length, ranging from 1 to 10 business days. For all Figures 5(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 5(a)-(c) summarize the findings using the “raw” CAD/USD, and Figures 5(d)-(f) summarize the findings using the “filtered” CAD/USD.

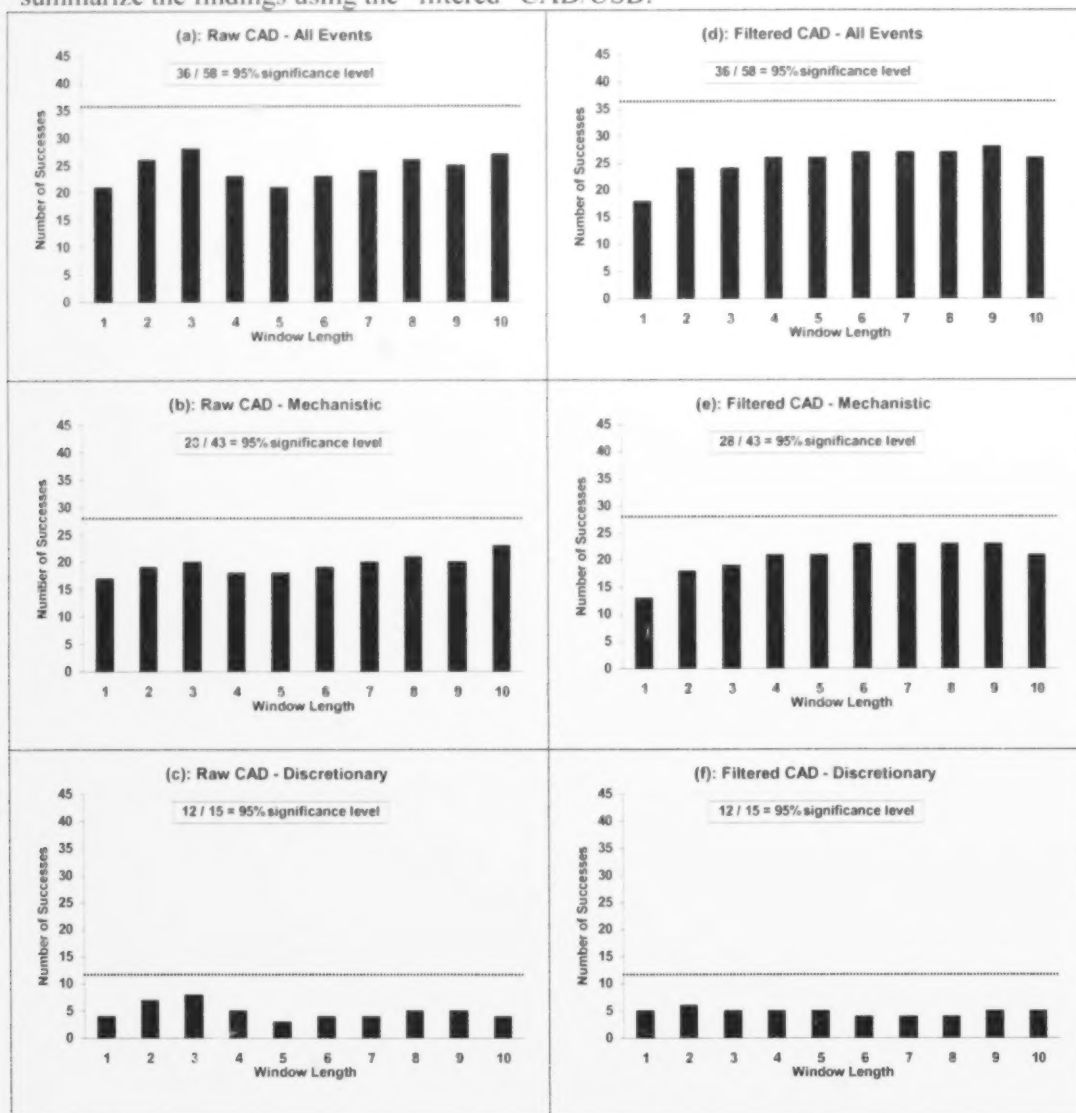


Figure 6: Success of Intervention Using High-Frequency Data — Direction Criterion

This figure shows the results for the sign test based on the "direction" criterion with the underlying probability parameter of 0.50. Intervention is a success when the CAD/USD moves in the direction of intervention after the event. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all Figures 6(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 6(a)-(c) summarize the findings using the "raw" CAD/USD, and Figures 6(d)-(f) summarize the findings using the "filtered" CAD/USD.

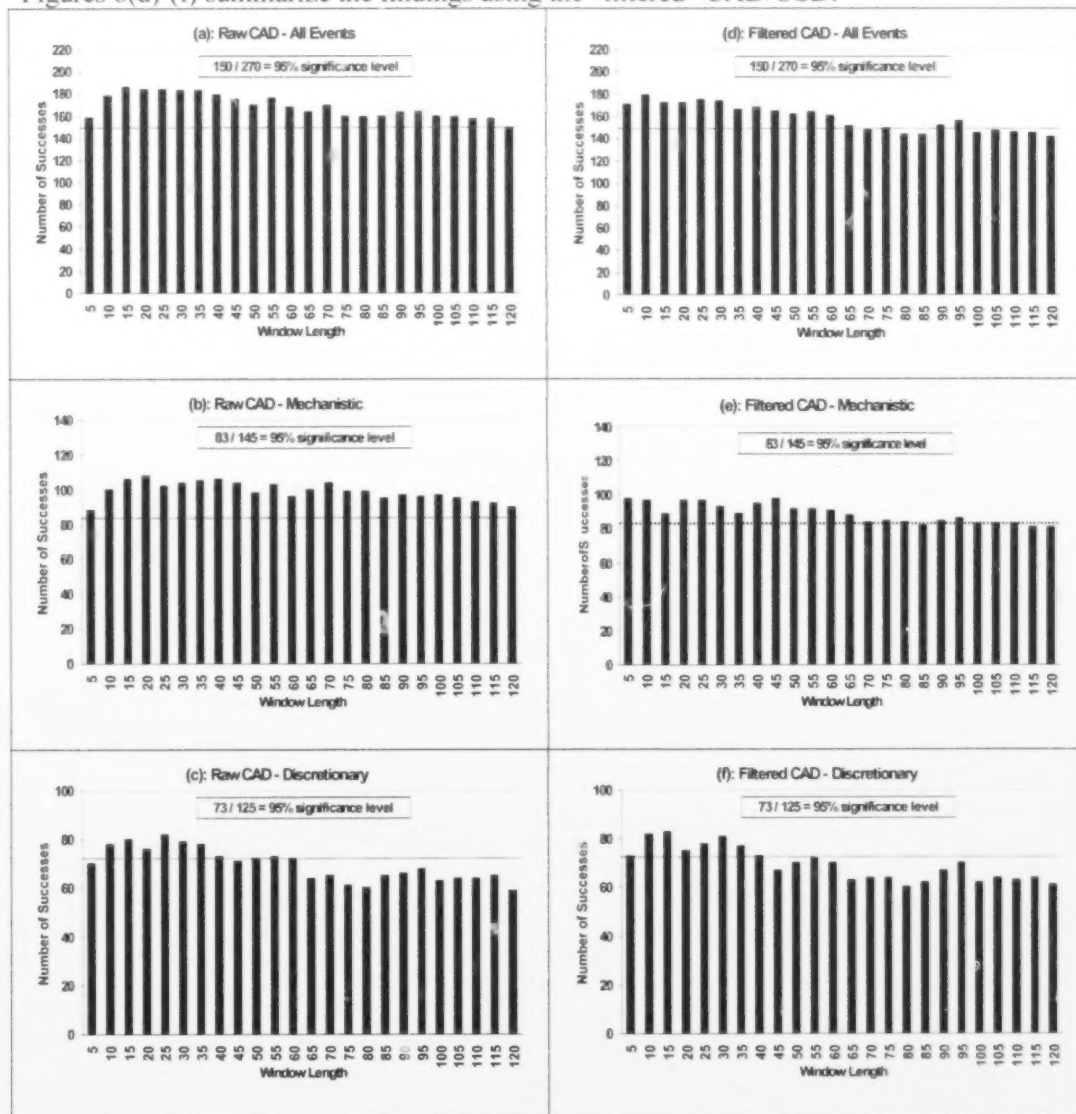


Figure 7: Success of Intervention Using High-Frequency Data — Smoothing Criterion

This figure shows the results for the sign test based on the “smoothing” criterion with the underlying probability parameter of 0.75. Intervention is a success when the CAD/USD changes direction due to intervention, or when the rate of change of the CAD/USD is slower following intervention. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all Figures 7(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 7(a)-(c) summarize the findings using the “raw” CAD/USD, and Figures 7(d)-(f) summarize the findings using the “filtered” CAD/USD.

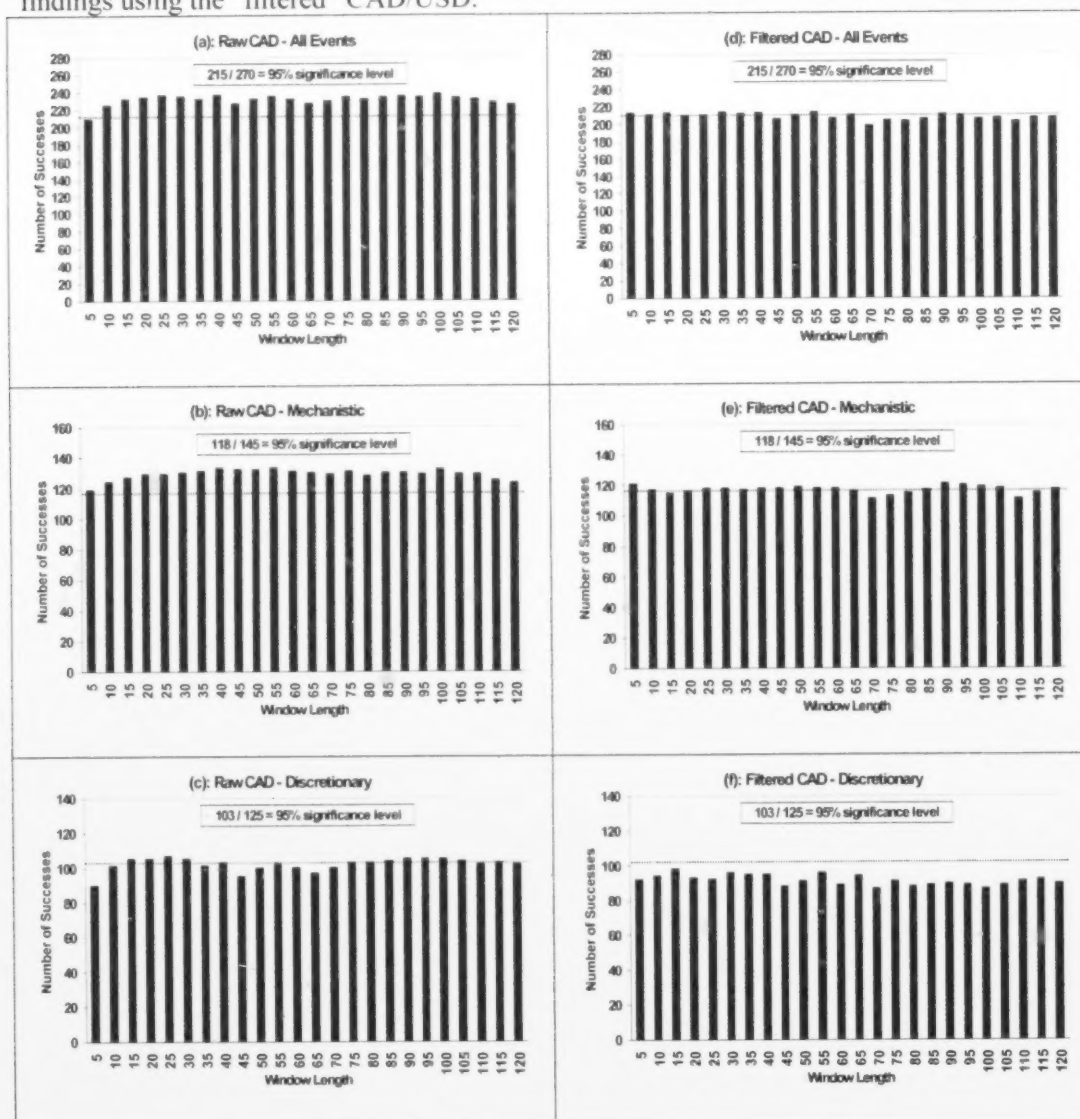
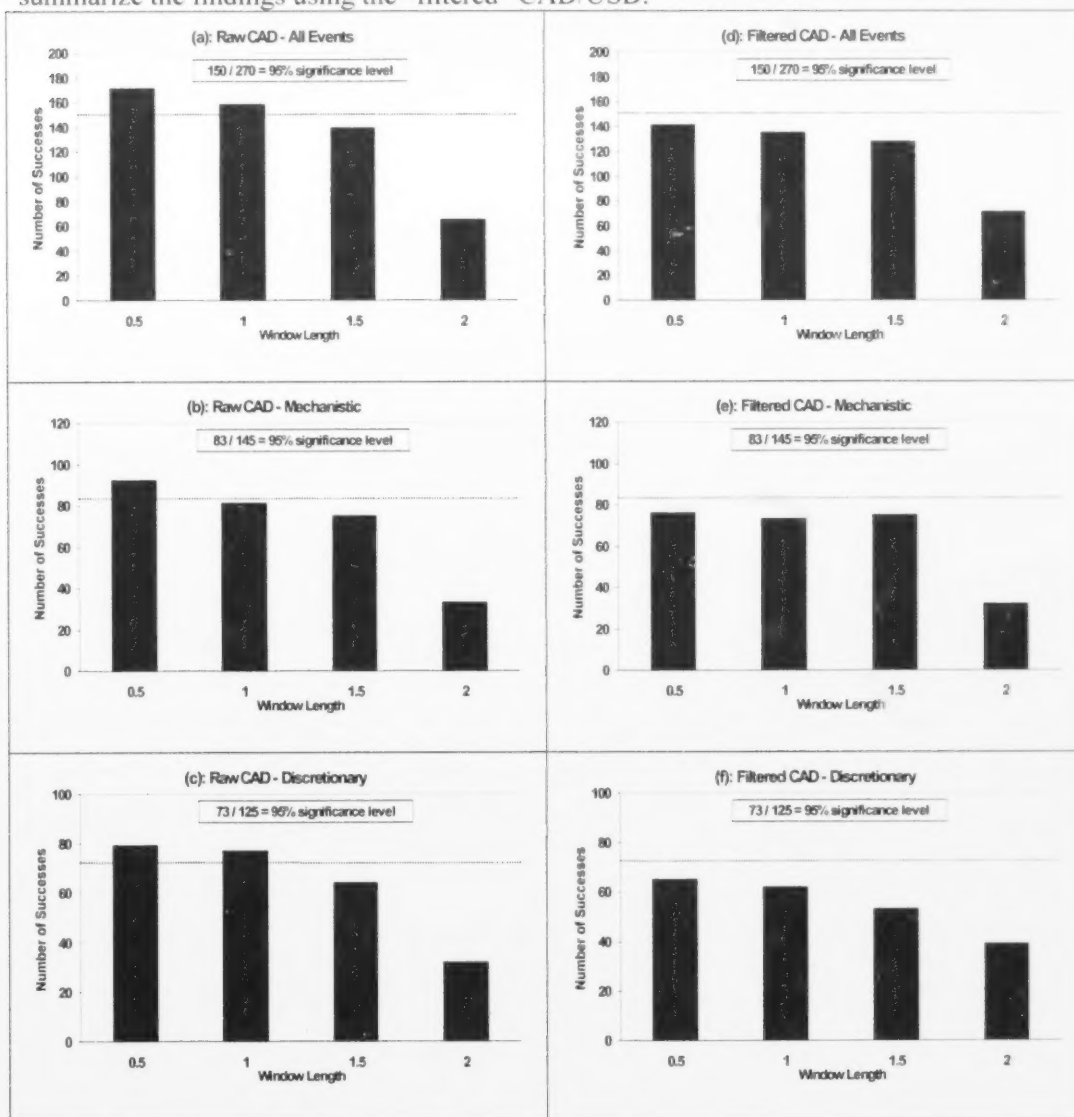


Figure 8: Success of Intervention Using High-Frequency Data — Volatility Criterion

This figure shows the results for the sign test based on the “volatility” criterion with the underlying probability parameter of 0.50. Intervention is a success when volatility decreases from before to after the event. Each column represents the number of successes based on a different window length, ranging from 0.5 hours to 2 hours. For all Figures 8(a)-(f), the horizontal line shows the number of successes necessary for rejecting a random outcome at the 95 per cent significance level. Figures 8(a)-(c) summarize the findings using the “raw” CAD/USD, and Figures 8(d)-(f) summarize the findings using the “filtered” CAD/USD.



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